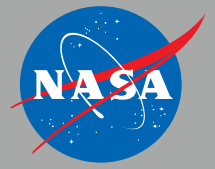

Packaging Concerns/Techniques for Large Devices

Seminar Topic

Presentation Military and Aerospace Programmable Logic Devices (MAPLD)

NASA Goddard Space Flight Center
August 31, 2009

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FPGAs- A Sampling of Challenges

Can we "qualify" without breaking the bank?

New Connectors

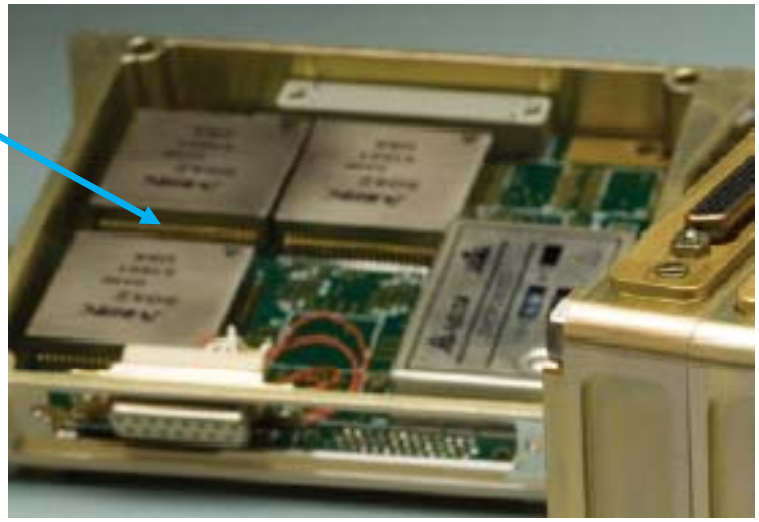
-higher-speed, lower noise

-serial/parallel

New Silicon

-90nm CMOS

-new materials



New Board Material

-thermal coefficients

-material interfaces

New Architectures

-new interconnects

-new power distribution

-new frequencies

New Workmanship

-inspection, lead free

-stacking, double-sided

-signal integrity

New Design Flows/Tools

-programming algorithms, application

-design rules, tools, simulation, layout

-hard/soft IP instantiation

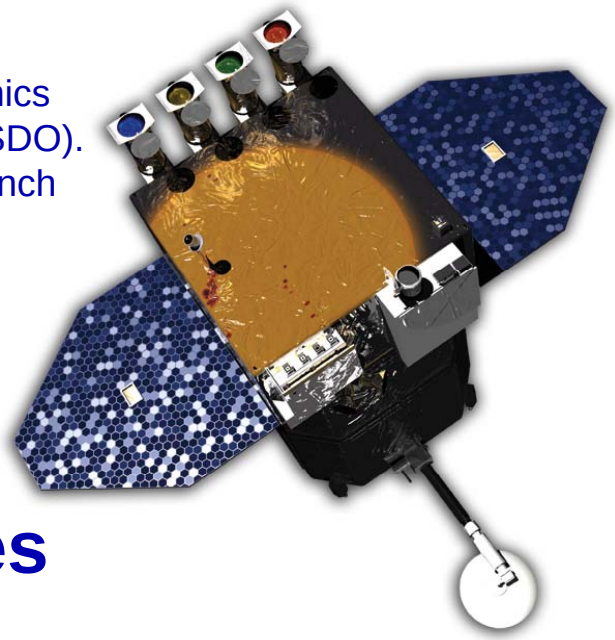
New Package

-Inspection

-Lead free

Where we were ©2006

Overview



Solar Dynamics Observatory (SDO). Awaiting Launch

- Packaging Challenges
- Packaging Options
- Components of All Packages
- Commercial, Non-hermetic Packages
- Space Challenges to Packages
- A Non-hermetic, Complex Package for Space
- Hermeticity, Why Space Users Like It
- Non-hermetic, Complex Package Variations
- Class X
- Summary

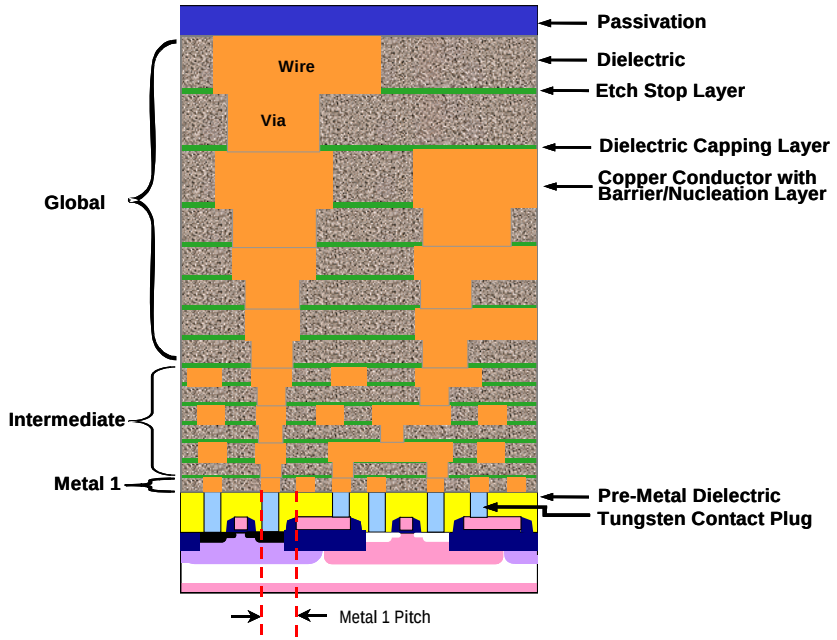
Packaging Challenges

- I/O s, increasing number, decreasing pitch
- Heat Dissipation, especially in space
- Manufacturability
- Materials
- Mechanical
- Installation
- Testability
- Inspectability
- Space Environment
- RoHS (Pb-free)

Lunar Reconnaissance Orbiter (LRO), Built at GSFC, Launched with LCROSS, June 18,2009

Package Options – Hermetic?

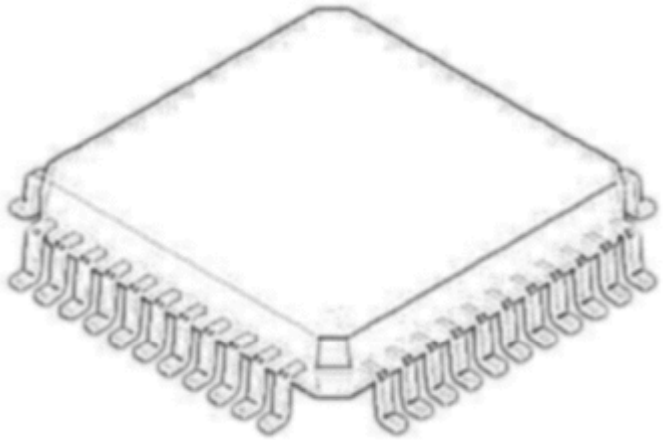
- Driven by consumer products
  - Low cost
  - High volume
  - Rapid turnover
  - “Green”
  - Minimized size



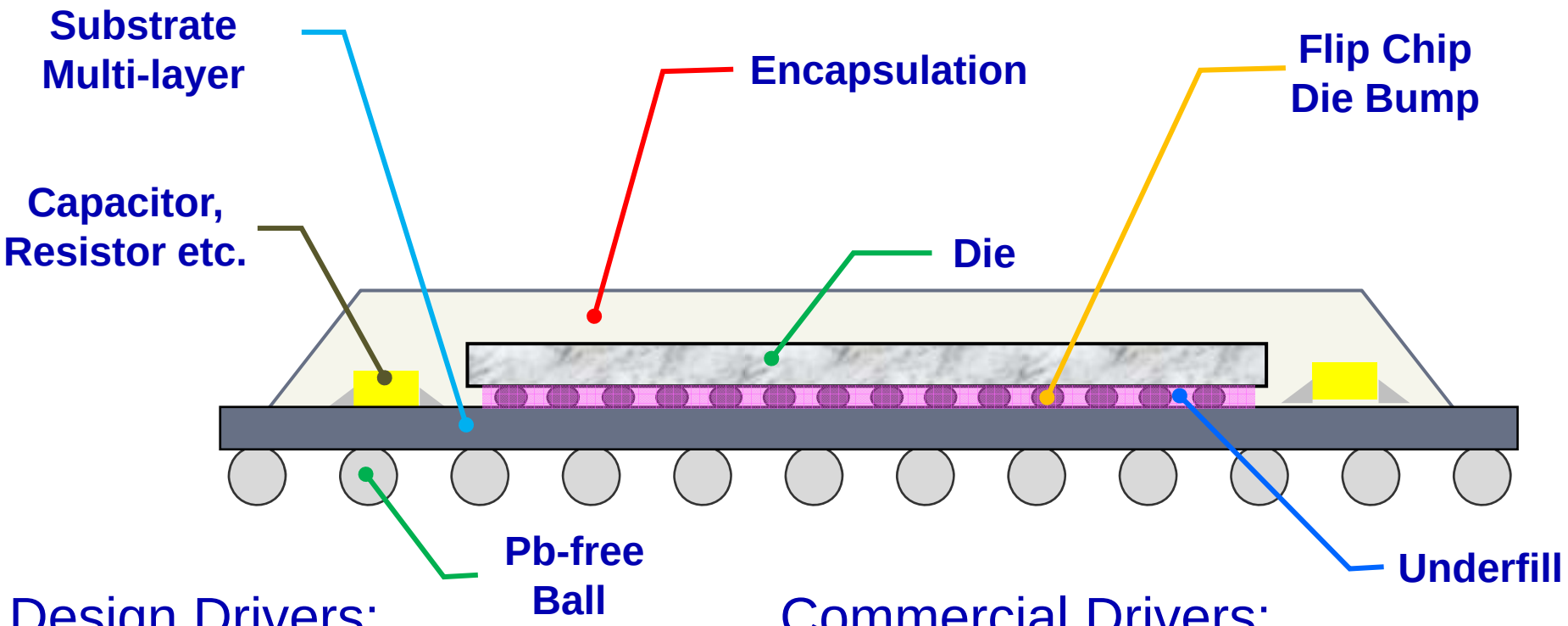
- Once, hermetic options existed for most package types
  - Now, few hermetic options for latest package technologies
  - Development of new hermetic options unattractive
    - » Very high NRE
    - » Very high technical difficulty
    - » Very low volume
    - » Demanding customers

The "General" Package

- **Typically, packages consist of the same basic features but achieve them in many ways:**
  - **Functional elements - active die, passives etc.**
  - **Interconnects between elements (2 or more elements)**
  - **A substrate**
  - **Interconnects to the external I/O of the package**
  - **A protective package**
  - **Interconnects to the next higher level of assembly**



Commercial, Non-hermetic Package (PBGA)



Design Drivers:

- High I/O count
- Large die
- Environmental protection
- Performance/Speed
- Ancillary parts

Commercial Drivers:

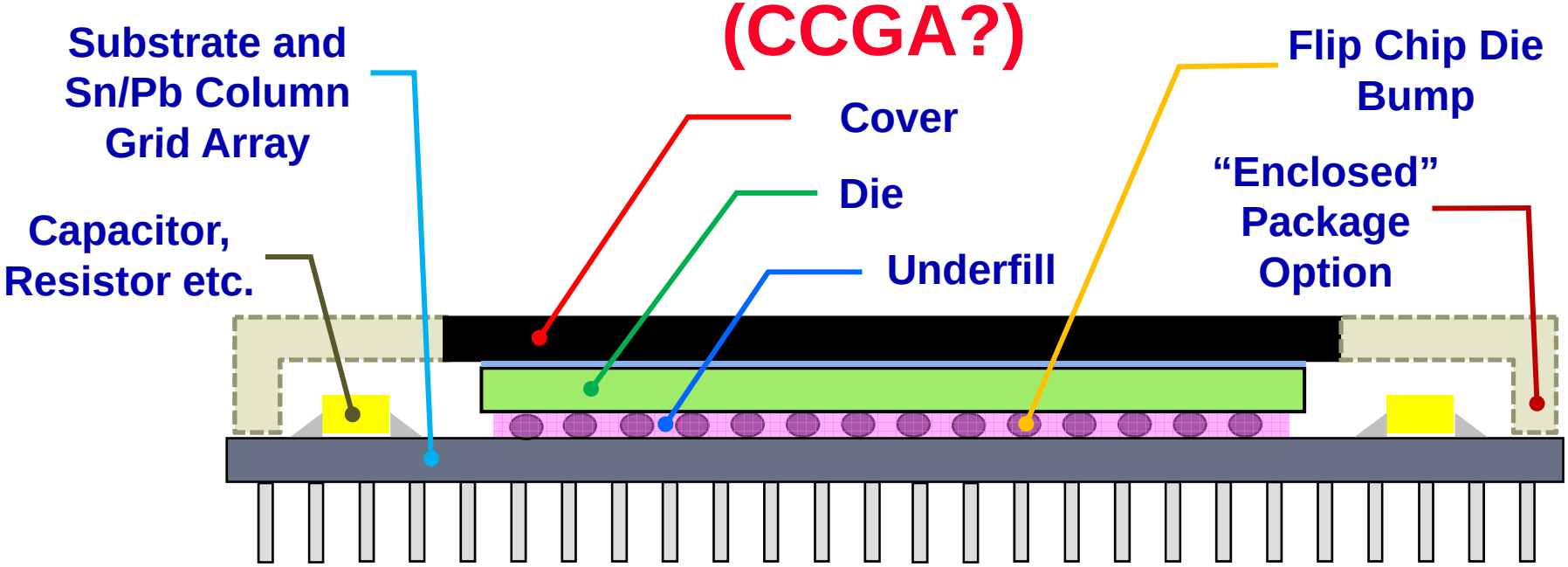
- Low cost
- High volume
- Limited life
- Automated installation
- Compact

Space Challenges for Complex Non-hermetic Packages

- **Vacuum:**
  - Outgassing, offgassing, property deterioration
- **Foreign Object Debris (FOD)**
  - From the package threat to the system, or a threat to the package
- **Shock and vibration**
  - During launch, deployments and operation
- **Thermal cycl**ing
  - Usually small range; high number of cycles in Low Earth Orbit (LEO)
- **Thermal management**
  - Only conduction and radiation transfer heat
- **Thousands of interconnects**
  - Opportunities for opens, intermittent - possibly latent
- **Low volume assembly**
  - Limited automation, lots of rework
- **Long life**
  - Costs for space are high, make the most of the investment
- **Novel hardware**
  - Lots of “one offs”
- **Rigorous test and inspection**
  - To try to find the latent threats to reliability

ONE STRIKE AND YOU’RE OUT!

Non-hermetic Package, With"Space" Features (CCGA?)



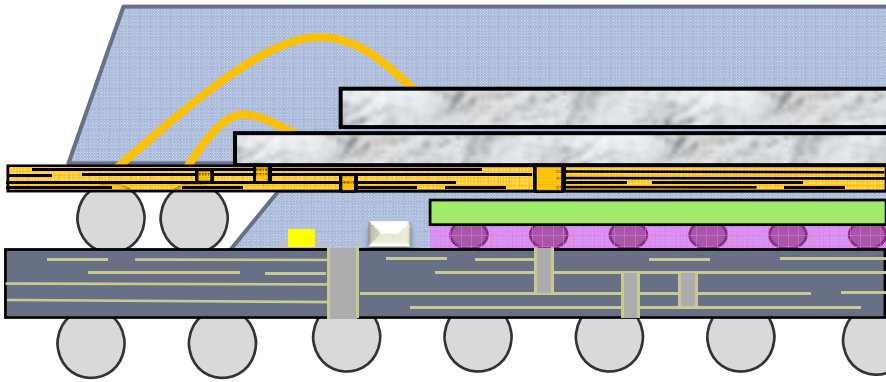
Space Challenge	Some Defenses
Vacuum	Low out/off-gassing materials. Ceramics vs polymers.
Shock and vibration	Compliant / robust interconnects - wire bonds, solder balls, columns, conductive polymer
Thermal cycling	Compliant/robust interconnects, matched thermal expansion coefficients
Thermal management	Heat spreader in the lid and/or substrate, thermally conductive materials
Thousands of interconnects	Process control, planarity, solderability, substrate design
Low volume assembly	Remains a challenge
Long life	Good design, materials, parts and process control
Novel hardware	Test, test, test
Rigorous test and inspection	Testability and inspectability will always be challenges

Hermeticity

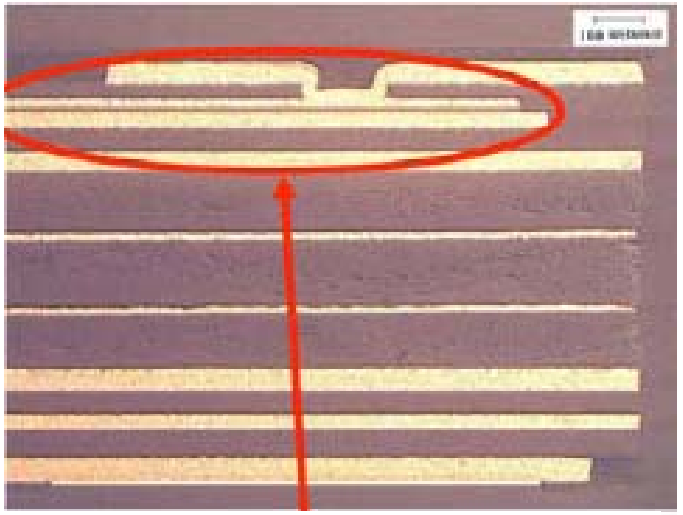
- **NASA prefers hermetic packages for critical applications**
- **Hermeticity is measureable, assuring package integrity**
- **Only 3 tests provide assurance for hermetic package integrity:**
  - **Hermeticity – nothing bad can get in**
  - **Residual or Internal gas analysis – nothing bad is inside**
  - **Particle Impact Noise Detection – no FOD inside**
- **NON-HERMETIC PACKAGE INTEGRITY IS HARD TO ASSESS - NO 3 BASIC TESTS**

Non-hermetic Package Variations

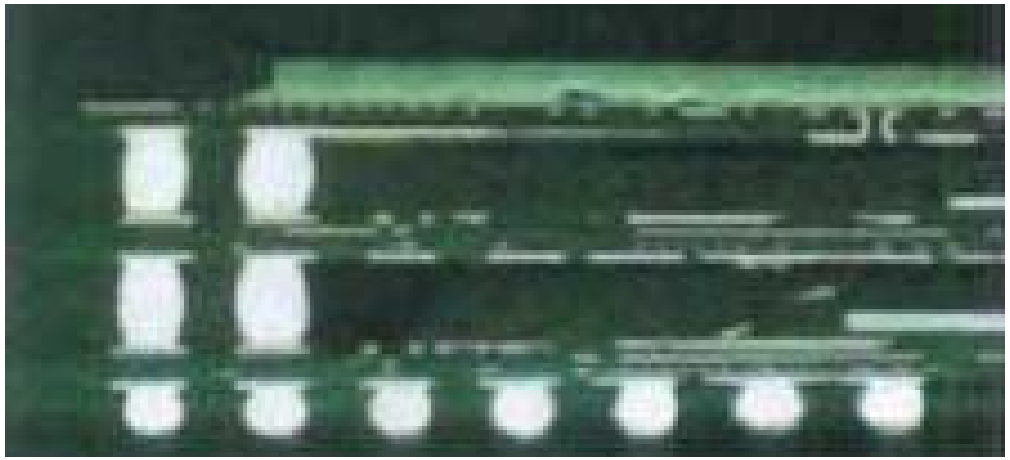
- **Current and future package options mix and match elements in almost infinite combinations**
- **Elements include:**
  - **Wire bonds**
  - **Ball interconnects**
  - **Solder joints**
  - **Conductive epoxies**
  - **Vias**
  - **Multi-layer substrates**
  - **Multiple chips, active and passive (hybrid?)**
  - **Stacking of components**
  - **Embedded actives and passives**
  - **Polymers**
  - **Ceramics**
  - **Enclosures/encapsulants**
  - **Thermal control features**

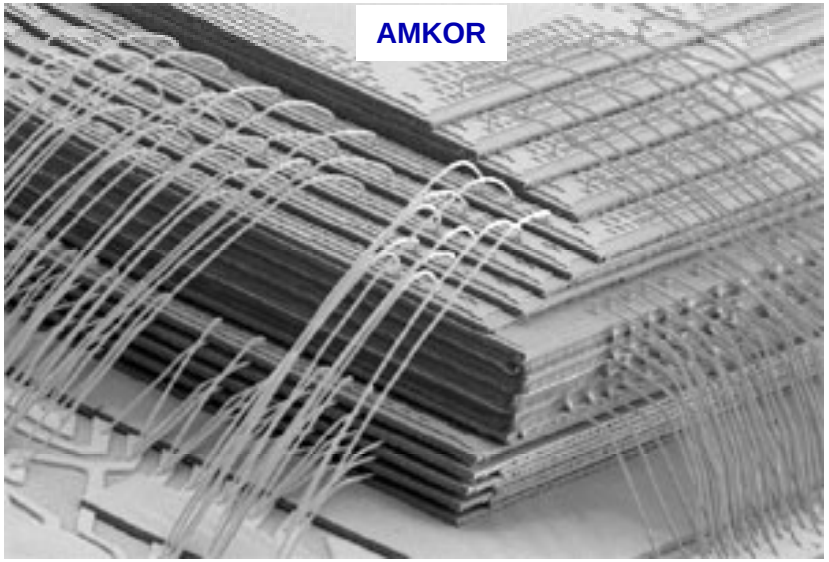


Some Large Device Package Options

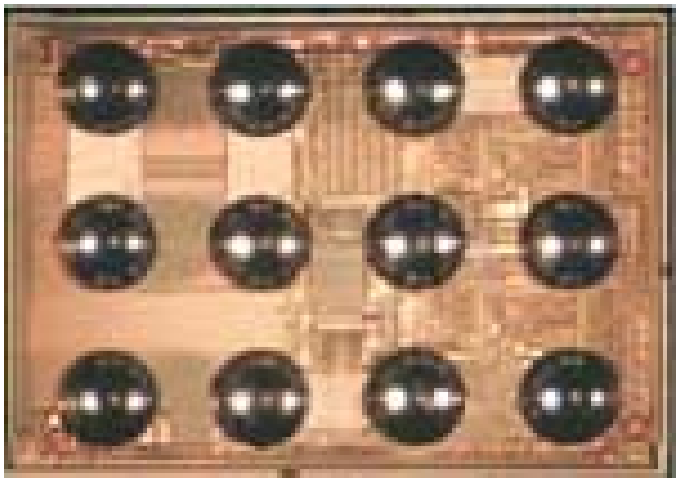


Embedded Capacitor



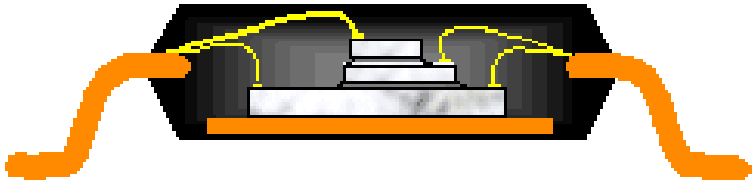


Some Large Device Package Options



2 Die Stack

3 Die Stack



6 Die Multi-Chip Module
Stacked Die ePad LQFP

From Amkor's Website http://www.amkor.com/go/packaging

Why MIL Spec. for Space ?

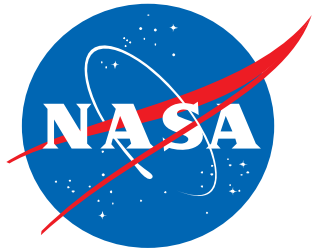
- **Space users like MIL spec. parts because:**
  - **There are technical "rules" that apply equally to all suppliers**
  - **Qualification to recognized requirements**
  - **Visibility of change control**
  - **Required tests and inspections reduce or eliminate the need for the space user to do post-procurement tests**
  - **Transparent government process for reacting to performance issues**
  - **Space level participation provides an opportunity to do continuous improvement of the MIL supply chain for Class S (space grade) microelectronics**
  - **Our experience says <u>They Work</u>**

Class X

- Proposed new class for MIL-PRF-38535
- Class X will be for Space level non-hermetic
- Class V will be defined as hermetic only
- Addition to Appendix B, “Space Application”
- Package-specific “package integrity” test requirements proposed by manufacturer, approved by DSCC and government space
- The Package Integrity Test Plan must address:
  - Potential materials degradation
  - Interconnect reliability
  - Thermal management
  - Resistance to processing stresses
  - Thermo-mechanical stresses

Summary

- NASA is going to have to accept the use of non-hermetic packages for complex devices
- There are a large number of packaging options available
- Space application subjects the packages to stresses that they were probably not designed for (vacuum for instance)
- NASA has to find a way of having assurance in the integrity of the packages
- There are manufacturers interested in qualifying non-hermetic packages to MIL-PRF-38535 Class V
- Government space users are agreed that Class V should be for hermetic packages only
- NASA is working on a new Class for non-hermetic packages for M38535 Appendix B, “Class X”
- Testing for package integrity will be required but can be package specific as described by a Package Integrity Test Plan
- The plan is developed by the manufacturer and approved by DSCC and government space



http://nepp.nasa.gov